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12 January 1940

NRL Report No. H-1585

NAVY DEPARTMENT

Report

on

NAVAL CAMOUFLAGE

Tests at Sea of June to September, 1939.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

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ABSTRACT

Experiments from May to September 1939 with Navy ships at sea led to many conclusions; some of which are:

1. Standard Navy gray was of low visibility in overcast, hazy and foggy weather, but was too light in bright weather and under searchlight.
2. Ocean gray was of low visibility in bright weather.
3. Black was of lowest visibility in day viewed from air and under searchlight.
4. Black was best for destroyers in view of their mission.
5. Dazzle camouflage of destroyers had more bad features than good ones.
6. Graded painting on light cruiser gave some deception worthy of further consideration.
- *7. Unobtrusive dazzle camouflage of tender produced some deception without increased visibility.

A table of the visibility of ships of various colors under various conditions is in Chapter 2.

In the light of present knowledge, it is suggested that (1) all Naval surface ships except destroyers be a 9 per cent dark mat gray, and that destroyers be mat black; (2) all merchant type ships be a 9 per cent or 18 per cent mat gray, with some unobtrusive dazzle and some graded.

Further experiments recommended are: (1) test 9 per cent dark gray and ultramarine blue on destroyer, (2) test ocean gray and 9 per cent gray on cruiser, (3) test graded system on 6-inch cruiser, (4) paint 6-inch cruiser to simulate 8-inch cruiser, (5) obtain data on visibility of wakes, and (6) test unobtrusive dazzle on cargo ship.

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CHAPTER 1

INTRODUCTION

Authorization

1. The continuance of the investigation of ship camouflage was authorized by Bureau of Construction and Repair confidential letter SI9-(7)(RI) of 6 May 1939.

References

2. References pertinent to the present report are:

Reference: (a) "Handbook on Ship Camouflage," Bureau of Construction and Repair, February 1937, prepared by Naval Research Laboratory.

(b) NRL Report No. H-1496, 9 December 1938, "Naval Camouflage, Tests at Sea of May and June 1938."

(c) Comdesdiv FIVE ltr. to Comdesbatfor, 1 December 1939, "Camouflage Painting of Surface Vessels." The letter is reproduced in full in the Appendix.

Historical

3. Investigation of various aspects of ship camouflage, initiated in 1935 by the Bureau of Construction and Repair and continued since that time, led to a number of conclusions summarized in references (a) and (b). It was found that standard Navy gray was of lowest visibility in hazy, foggy and overcast weather, but was very visible in sunny weather and under searchlight and moonlight illumination at night. It was easily visible from the air. Ocean gray was of low visibility in sunny weather and was not particularly revealing when viewed from the air and under searchlights at night. Black was of lowest visibility viewed from the air and under searchlights at night. It was concluded that no one color of paint combined all advantages and that a color finally chosen must be a compromise governed by the projected employment of the camouflaged ships. Many of the facts were derived from observations which extended over short periods of time and a small variety of weather conditions in a single sea area.

4. It appeared that little further knowledge was to be gained from short time isolated experiments and that an attempt to arrive at final conclusions would require wide scale experimentation with several ships under operating conditions for considerable periods of time.

Scope of the Present Report

5. From May to September 1939, experimentation was carried out with three destroyers enroute from Norfolk, Virginia, to San Diego, California,


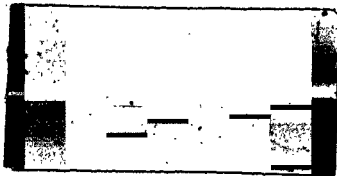
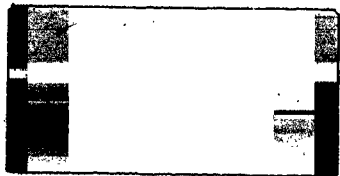

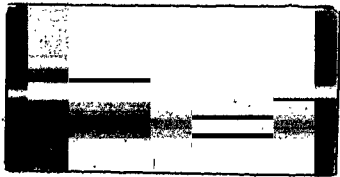
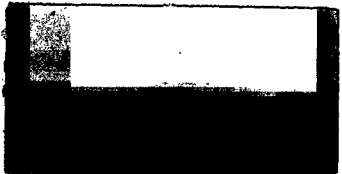
via the Panama Canal, with ships in the San Diego area and with destroyer divisions operating in a Fleet tactical problem in the Pacific Ocean off Long Beach. The results with details, discussion and recommendations were given in reference (c), which because of its importance, thoroughness, and completeness is reproduced in full in the Appendix. The present report is based entirely on reference (c) with some comments and suggestions. The subjects of low visibility and dazzle camouflage of surface ships are dealt with. Although no pains have been spared to make the report brief, complete and above all correct, our advice to the reader is that if there is any skipping to be done, he skip this report and read reference (c).

Recording Color

6. All of the colors referred to in this report are shown in Plate 1 with their Munsell notations and percentage reflectivities. In considerations of low visibility, the brightness of a color is an important attribute. Brightness is the percentage of white light falling on the color diffusely reflected by the color as measured by a light adapted normal eye. (The artist often uses the word "value" to describe the "brightness" or the "darkness" of a color.)

7. It is hardly necessary to remark that inspection in a room of a small sample of color in a book can not give the proper impression of a ship painted with the color.

8. Further, the colors of Plate 1 must not be used in preparing paints for they may fade or otherwise change with time; Plate 1 was merely for the purpose of giving the reader an approximate idea of the color. Colors of paints must be mixed by reference to panels prepared from the Munsell Book of Color or from known formulae.

	Name	Munsell Notation	Reflectivity Per Cent
	Standard Navy Gray	Neutral 6.2/ to 6.8/	30 to 35
	Ocean Gray	Neutral 5.0/ to 5.4/	18 to 20
	Standard Deck Dark Gray	Neutral 3.4/ to 3.8	8 to 10
	Black	Neutral 1.5/ to 2.5	2 to 4
	Ultramarine Blue	Purple-Blue- Purple 3/12 (Approximately)	8 to 10
	Dark Green	Green 2/2	3 to 5

Low Visibility Colors

Plate 1

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CHAPTER 2

LOW VISIBILITY PAINTING OF DESTROYERS

Colors for Lowest Visibility

9. Four colors were tested on destroyers. The colors, shown in Plate 1, were standard Navy gray, ocean gray, dark green, and black. All decks were painted with standard dark gray deck paint. The color was painted on all vertical surfaces, and on all masts, stacks, rails, rigging, guns, boats and canvas. It was also painted on all horizontal surfaces except those already covered with the standard dark gray deck paint. Thus the destroyer presented to the observer only the color under investigation and the standard deck paint.

10. The results of long continued tests, reference (c), by many observers of the relative visibility of the various colors on the destroyers are summarized in Table 1. The notes appended to the table are for the most part quoted verbatim from reference (c) and serve to bring out certain important points not readily reduced to tabulation. (We insert here the remark that the table is a drab sketch of dusty facts, whereas a close reading of reference (c) permits occasional glimpses of a moving pageantry of ships and men at sea and in the air. The remark is out of place in a dull report to a Bureau of materiel.)

TABLE 1

Color for Low Visibility

Position of Observer	Conditions			Color for Lowest Visibility	
	Day	Night	Weather, illumination, etc.	Vertical Surfaces	Horizontal Surfaces
On surface	Day		Clear sky, sunny, no haze.	Ocean gray	Usually not seen
	Day		Cloudy sky, no sun, no haze.	Navy gray	
	Day		Haze or fog.	Navy gray	
	Day		Black smoke screen.	Dark colors	
	Day		White smoke screen.	Light colors	
		Night	Natural illumination, stars or clouds, no moon.	Black	
		Night	Clear sky, moon behind observer.	Black	
		Night	Moonlight, diffused through clouds.	Ocean gray	
		Night	Searchlight illumination from observing ship, or from behind observer.	Black	
		Night	Far side of target from observer illuminated by searchlight, flare, star shell.	Target in silhouette, all colors alike.	
In air	Day		All conditions of weather and illumination.	Black	Black
		Night	All conditions of weather and illumination.	Black	Black

Note 1. In silhouette against the sun, moon, searchlight or other source of light all colors look alike and camouflage is of no effect.

Note 2. No color affects appreciably the accuracy of stereo-ranges.

Note 3. Dark green is almost the same as black but not quite as satisfactory.

Note 4. In the daytime black ships are visible at long ranges as objects but target angles and ranges, because of indistinctness of shadows, are much more difficult to determine than with lighter paints.

Note 5. When observed from the air at distances 1 to 8 miles, altitudes 1000 to 2000 feet, the black ships of DIVISION FOUR were not visible over two or three miles, while the standard gray ships were visible at all distances. The black ships were less visible than the green. Sun glints and light spots aided in locating the destroyers. The visibility of the dark ships was 1/3 to 1/4 that of a standard gray ship.

Note 6. At speeds above 12 knots the white wake of a destroyer becomes important. At night and from aircraft at any time when destroyers are making speeds of 20 knots and above the wakes are so apparent that little advantage can be had from camouflage. At night under searchlight high speed wake is clearly visible and readily discloses the presence of a destroyer regardless of painting.

Note 7. Gloss is objectionable in any color. It is most apparent on stacks and gunshields and is most noticeable with black.

Choice of Black as Low Visibility Color for Destroyers.

11. Regarding the choice of a low visibility color for destroyers, reference (c) draws the following conclusions:

"1. Standard Navy gray is not satisfactory either for daytime or night.

"2. A color much darker than Navy gray and darker than ocean gray is indicated.

"3. Preference for the three colors tested is, in order, black, ocean gray, standard gray. Black meets the requirements for improved visibility at night, in accordance with Commander Battle Force's directive that daytime visibility may well be sacrificed for decreased visibility at night.

"4. All surfaces visible from the air should be black or a color approaching black."

12. Reference (c) discusses the choice of black or a very dark color as follows:

"Ocean gray is in the color scale between black and the standard gray. On a bright sunny day it is reported by observers from surface vessels as the least visible of the three colors and compares favorably with either of the other two colors under any chosen conditions. It does not appear white under concentrated illuminations as does the standard gray and is less striking than black on a clear bright day. If the aerial observations were excluded, it is believed that ocean gray, or a somewhat darker gray, would be chosen by the majority as the best compromise color. It is believed, however, that preference for the ocean gray over the black is influenced by the following factors:

"Natural aversion to solid black ships, especially flat black, from standpoint of smartness and difficulty of upkeep.

"In daylight the black ship presents a silhouette which is more plainly delineated than the ocean gray and therefore is said to be more visible.

"The first of these factors, smartness and cleanliness, although not a part of this investigation, will inevitably influence the opinions of officers who go to sea on surface vessels. The second factor is in part an optical illusion. A black ship is more striking than a gray ship even at close range. It is therefore said to be more visible, despite the fact that definition of detail is better in the case of the gray ship and therefore the target angle is easier to estimate.

"It is believed that the ocean gray tested is too light a gray and that if gray be chosen, it should be considerably darker. A dark gray would have most of the advantages of black and would probably meet most of the objections advanced to black. The results of the tests seem to point to a very dark color - darker than ocean gray. A conclusion as to how far short of black the color could be can not be drawn from these experiments."

Mat and Glossy Paint.

13. Reference (c) states:

"Gloss is objectionable in any color.

"All paint furnished was of a relatively high gloss.

"Gloss paints materially aid in disclosing the ship under any form of concentrated light day or night. It is most noticeable with the darker paints."

Masts of Destroyers.

14. Reference (c) concludes:

"Black masts and similar high structures are very revealing when they alone protrude above the horizon. Standard Navy gray color is believed to be best for them. It is believed masts can be painted standard gray without materially increasing visibility."

Various Details.

15. When the visibility of the ship is lowered by proper choice of the color, various details which before seemed to be entirely inconsequential become important. Reference (c) states:

"A related subject is the elimination of exterior reflecting surfaces - these include bridge windows, ports, port rims, turnbuckles, whistles, gun parts, binnacles, bridge woodwork, such as varnished benches and boat decks.

"Exposed life ring buoys should be the same color as the surrounding surfaces."

16. Each of the above details presents a small and separate problem, all of which can probably be solved by means of paint and painted canvas covers, except perhaps the bridge windows. These should be inclined outboard about 10° from the vertical, or it may be sufficient merely to lower them in bright sunshine, moonlight or previous to searchlight illumination, in order to eliminate possible bright reflections.

17. The fact that such a small object as a life ring buoy needs attention indicates pretty strongly that white uniforms are out of place on the deck of a dark colored ship during wartime.

Suggested Experiments with Low Visibility Colors Dark Gray and Ultramarine Blue.

18. Reference (c) suggests tests of a gray somewhat darker than ocean gray. A gray of reflectivity about 9 per cent would appear to be suitable for test. The color is about that of standard dark deck paint, Plate 1. In daylight it is considerably darker than ocean gray and appreciably lighter than black. A dark blue gray of 9 per cent reflectivity could be used equally well as a neutral gray, for a slight color tint has no effect on visibility. A dark green gray could also be used but there appears to be no reason for using any shade of green on a Navy ship at sea.

19. Laboratory tests show that under searchlight illumination at night the 9 per cent gray is distinctly more visible than black, but whether the difference is important can only be determined by tests at sea.

20. In this connection a pure intense blue deserves consideration. The color is shown in Plate 1; it is usually described as "ultramarine blue." We have long realized that a pure vivid blue color possesses desirable low visibility features, but have believed that its proposal would be bizarre or in advance of the times. Now, however, in view of the clearer perception of the facts and the crystallization of opinion brought out in reference (c), it is timely to discuss the features of the blue color.

21. The Purkinje effect is the shift in the color sensitivity of the eye with the change from light adaptation to dark adaptation, the sensitivity of the eye for blue light relative to the sensitivity for red light increasing very greatly with the change from light to dark adaptation. For example, in full daylight or sunlight the blue of Plate 1 is about as dark as the 9 per cent gray, but under weak illumination, as twilight or moonlight or less, the blue appears nearly, but not quite, as light as Navy gray. Experiment also shows that under searchlight illumination the blue appears darker than the 9 per cent gray and nearly as dark as 4 per cent black; this is due partly to the weakness of the blue wavelengths in the searchlight spectrum relative to those of the daylight spectrum, and partly to the light adaptation of the eye when looking at a target illuminated by a searchlight. Indeed, with a blue target it is a surprising sensation to see dimly in the dark what appears to be a light grayish object, and then to turn the searchlight on the object merely to discover with difficulty what appears to be a very dark object; the surprise is occasioned by the fact that the searchlight is of unexpectedly little aid in revealing the object.

22. The estimated appearance of a ship with all vertical surfaces painted intense blue is as follows:

Day, sunshine, at near distances, should appear very blue; at far distances, should be of as low visibility as ocean gray; shadows should be indistinct and target angles should be as difficult to determine as for a black ship.

Day, overcast, should be of as low visibility as ocean gray.

Twilight, unless silhouetted against bright sky, should be of as low visibility as ocean gray.

Night, natural illumination, should be equal to ocean gray.

Night, searchlight illumination, should be equal to black or nearly so.

Both day and night, should be of as low visibility from the air as black.

In day, in fog and haze and hence at near distances, should probably not be of as low visibility as Navy gray.

29. Although painters regard ultramarine blue as among the stable pigments, its stability and permanence on a chip at sea are not known. Specific experiments with the 9 per cent dark gray and the ultramarine blue are outlined in Chapter 6.

CHAPTER 3

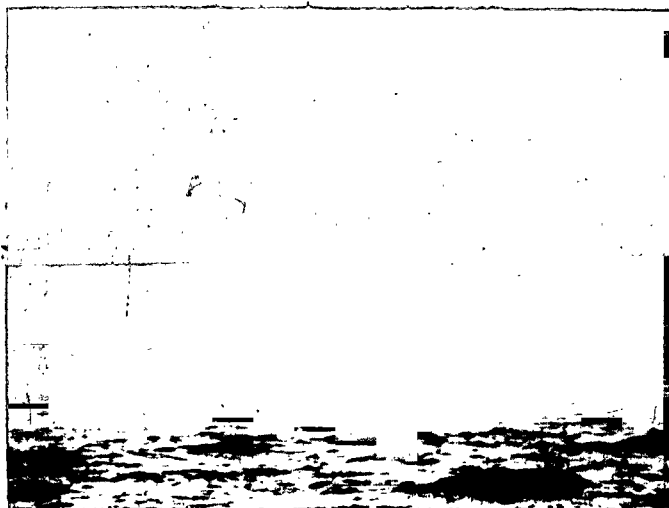
DAZZLE PAINTING OF DESTROYERS

24. The 1938 camouflage tests with destroyers, reference (b), showed that a dazzle pattern disturbed course estimation to some extent but at the expense of increased visibility. It was suggested that a dark dazzle pattern would be a compromise which might disturb course estimation at short ranges without greatly increased visibility at long ranges.

25. The destroyer CONYNGHAM was painted with a bold pattern of black and ocean gray; its photograph is in Plate 2. Observations of this ship in the San Diego area from July 31 to September 1, 1939, led to the conclusion stated in reference (c) that:

"The dazzle design is confusing under certain conditions-but not sufficiently so to warrant further consideration for destroyer painting."

The conclusion, added to those of reference (a), effectively relegates the matter of dazzle painting of destroyers to the category of things that are not worth doing.



CONYNGHAM

*DARK DAZZLE PATTERN ON DESTROYER
PLATE 2*

CHAPTER 4

GRADED SYSTEM ON LIGHT CRUISER

26. The graded system is for the purpose of producing deception in range estimates by painting the vertical sides of the hull with horizontal stripes which are dark (or black) at the water line and become successively lighter to the gunwale. It makes little difference whether the stripes are shaded into each other or not. In the 1938 tests, reference (b), with the graded system on two destroyers it was concluded that the system produced a slight illusion of range due to the dark stripe at the waterline. The graded destroyer appeared to be roughly 15 per cent farther away than a standard Navy gray destroyer, when the two were actually at the same distance.

27. In the present experiments, reference (c), the graded system was applied to the light cruiser RALEIGH. There was a black stripe 3 feet wide at the waterline, next a 3-foot wide stripe of 10 per cent gray, and next an 8-foot wide stripe of 18 per cent gray (ocean gray). This brought the painting to the gunwale of lowest freeboard. The raised forecastle and other remaining vertical surfaces of the hull were Navy gray (35 per cent reflectivity). An additional detail was that black smoke-pipe watch caps were painted with lower edges in a line tilted up from the horizontal. Photographs of the two ships at various ranges are shown in Plate 4.

28. The RALEIGH cruised in company with the DETROIT which was Navy gray and the two ships were observed during their scheduled operations in the San Diego area. From a summary of the observations, reference (c) stated:

- "1. The graded method does materially confuse range estimation.
- "2. In hazy weather the graded vessel was more easily discernible than the normal vessel.
- "3. In clear bright weather there is little choice of visibility of the two methods of painting.
- "4. Painting smoke-pipe watch caps at varied heights assists confusion of course estimation.
- "5. Possibility of being especially advantageous against submarine attacks where only a quick glance through a periscope is possible."

29. Reference (c) concluded:

- "(1) The graded system tends to distort the structural features of a vessel and confuse range and spotting estimates.

"(2) Unless the positions of the shaded bands are related to the position of the observer (and hence to the observer's horizon) the graded system is more visible than a solid color.

"(3) If standard Navy gray is to be retained for large vessels, it is believed that the graded system is worthy of further tests for large vessels."

29. It may be mentioned that because of the low freeboard aft of the RALEIGH, and hence the relatively small expanse of vertical surface of a large part of the hull, the graded system was probably not as effective as it would be on a type of ship of higher freeboard such as the 6-inch, 10,000 ton cruiser.

RANGE 7000 YARDS



RANGE 5000 YARDS



RANGE 3200 YARDS



RALEIGH GRADED

DETROIT NAVY GRAY

*GRADED PAINTING ON LIGHT CRUISER
PLATE 3*

CHAPTER 5

DAZZLE CAMOUFLAGE ON TENDER

30. Two dazzle designs to produce course distortion were painted on the destroyer tender MELVILLE, a bold design on the starboard side and an unobtrusive design on the port side. This is the first experiment with dazzle camouflage on a merchant type of vessel which has been performed since the last war. The unobtrusive camouflage may be said to be the one new idea in deceptive sea camouflage which has emerged since the last war. It is fully discussed in reference (a) and consists in painting a few artificial shadows for course deception in such an inconspicuous way that the observer does not realize that the vessel is camouflaged or that he is deceived. The unobtrusive camouflage does not increase the visibility materially.

31. The designs on the MELVILLE are shown in Plate 5. The starboard design is a variation of the design of Plate 14a, reference (a), and the port design is the design of Plate 18d, reference (a).

32. The MELVILLE was observed at sea on 5, 6, 7 and 8 September 1939, by various units. Reference (c) gives the following conclusions:

"1. The target was appreciably distorted by camouflage on both sides, especially from approximately 30° to 160° and 210° to 330°.

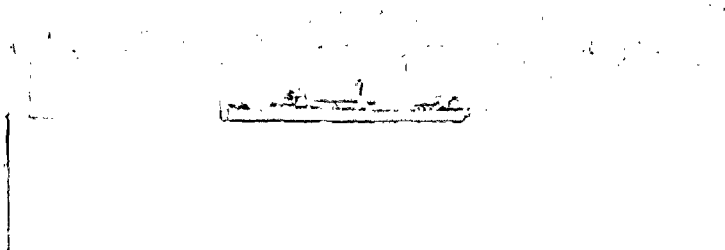
"2. The presence of camouflaging is less evident by method applied to port side than by that applied to starboard side."

33. The results of the experiment are important in bringing out the fact that an inconspicuous design, which did not augment visibility appreciably, was equally effective in producing course distortion as the bold dazzle design which increased visibility. Therefore, in so far as one can conclude anything from a single experiment, the conclusion follows that there is little need to consider further the bold designs, with their attendant disadvantage of high visibility, since the fundamental purpose of the design in causing course distortion is accomplished equally well by an unobtrusive pattern which does not enhance visibility.

TARGET
ANGLE

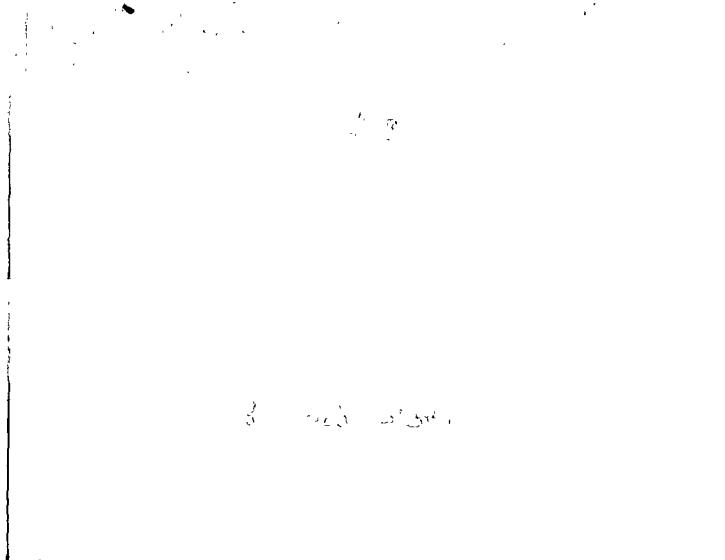


332°



270°

UNOBTRUSIVE DAZZLE DESIGN



032°

081°

BOLD DAZZLE DESIGN

DAZZLE DESIGN ON TENDER MELVILLE
PLATE 4

CHAPTER 6

SUGGESTIONS AND RECOMMENDATIONS

34. Table 1 contains an enormous amount of information, derived from a long program of experimentation, about the color of a ship for low visibility under various circumstances. The information has been obtained entirely from experiments with destroyers but is in all probability valid for any type of ship. The question arises whether Table 1 and the other chapters of this report contain all the necessary information or whether there remain gaps which should be filled in by further experimentation. Actually there are important gaps which it would be of advantage to remove, but it is of interest to discuss the question in two ways:

- (1) By suggesting the most effective painting of all Naval ships in the light of information available at the present time.
- (2) By outlining further tests which appear to be important in reaching a final decision about the painting of all Naval ships.

Suggested Painting of All Naval Ships in the Light of Present Knowledge.

35. Paint all classes of ships, destroyers, cruisers, battle ships, carriers, etc., throughout except for masts a dark gray, or a dark blue gray, about 9 per cent reflectivity. The color approaches black. Paint all pole masts Navy gray, about 33 per cent reflectivity. In particular, put the dark gray (or dark blue gray) color on all horizontal surfaces, all vertical surfaces, on all objects visible from the surface or the air. All bright work, varnished surfaces, shiny metal must be painted or put under dark covers. As little glass as possible must be left exposed and no white uniforms on deck.

36. All paint must be mat.

37. The advantages of the dark color, 9 per cent reflectivity, are that it is of low visibility from the air day or night and under searchlight. In daylight the color obscures details and interferes with course estimation; at moderate speeds it obscures the water line and interferes with range estimation (but has no pronounced effect on range finder measurements). The disadvantage of the color is that the ship is moderately or highly visible as an object in the daytime to a surface observer. The color is drab and dismal and may encounter dislike.

38. We qualify the above suggested universal use of 9 per cent dark color by adding that in the case of destroyers, for which lowest visibility under searchlight was desired, it would be best to paint all vertical surfaces black.

Suggested Painting of All Merchant Type Ships in the Light of Present Knowledge.

39. It would seem best to contemplate the following views for painting merchant type ships in wartime:

- (1) That bold dazzle designs of highly contrasting brightness ranging from black to Navy gray, and hence of high visibility, be eliminated entirely.
- (2) That only low visibility painting over the entire ship be used, as 9 per cent dark gray or 18 per cent ocean gray.
- (3) That the low visibility painting be supplemented in some cases by an unobtrusive dazzle which consists of a few dark spots to simulate shadows, the spots to be best adapted to each ship.
- (4) That the low visibility painting be supplemented in some cases by a simplified graded system consisting of a single black stripe at the water line, to give a raised water line, the system to be best suited to the type of ship; for example, it would be most suitable to a ship of high freeboard.
- (5) That all ships be not painted alike.

Recommended Further Experiments Important to Reaching a Decision about the Painting of All Naval Ships.

40. General for all experiments. All paint must be mat. All horizontal surfaces standard dark gray deck color, 9 per cent reflectivity. Therefore all the experiments below refer to painting the vertical surfaces and all surfaces not already covered with the dark gray deck color. All bright and shiny objects painted, covered or removed, down to the smallest details.

41. All experiments should be carried out over extended periods of time under all possible conditions of weather and types of illumination and missions.

42. The importance of assigning an officer to direct the tests can not be overemphasized; the success of the work of reference (c) was largely due to this one element. The officer should understand what the experiments are, what they are for, should direct the experiments, summarize the results, and write the report.

42. Experiment A. Object: To test visibility of 9 per cent dark gray (or 9 per cent dark blue gray), ultramarine blue on destroyers, and to determine the value of Navy gray masts.

Four destroyers, vertical surfaces painted as follows:

- (1) Navy gray with Navy gray masts for control.

- (2) Black with black masts.
- (3) 9 per cent dark gray with Navy gray masts.
- (4) Ultramarine blue with blue masts.

The vivid ultramarine blue is made by mixing pure ultramarine pigment with about 6 per cent by weight of a pure white pigment titanium oxide, or an equivalent amount of zinc oxide.

The experiment outlined above is a minimum experiment designed to test three things simultaneously: (1) effectiveness of 9 per cent gray vs. black, (2) effectiveness of ultramarine blue vs. black and ocean gray, (3) effectiveness of black, ocean gray and Navy gray masts. If more than four destroyers were available it would be better to spread the program into several experiments each designed to test one thing. For example: Experiment A1, First Division, two ships black, two 9 per cent gray; Experiment A2, Second Division, two ships black, two ultramarine blue; Experiment A3, Third Division, two ships ocean gray, two ultramarine blue; etc.

43. Experiment B. Object: To test visibility of ocean gray and 9 per cent dark gray on a large ship.

Three cruisers, vertical surfaces painted as follows:

- (1) Navy gray with Navy gray masts for control.
- (2) Ocean gray with ocean gray masts.
- (3) 9 per cent dark gray, Navy gray masts.

This experiment depends to some extent on Experiment A and logically should not be done until the results of Experiment A are known. For example, if the blue color of Experiment A turned out to be effective, the color might then be included in the cruiser experiment.

44. Experiment C. Object: To test graded system on a 6-inch, 10,000 ton cruiser.

Paint vertical surfaces of two 6-inch cruisers as follows:

- (1) Navy gray, for control.
- (2) Paint hull with three horizontal stripes from water line to gunwale, the lowest stripe black, the next stripe 9 per cent dark gray, and the upper stripe ocean gray, of widths 20, 40 and 40 per cent, respectively, of freeboard height; the superstructure Navy gray.

The six inch cruiser, because of its relatively high freeboard throughout its entire length would seem to be well adapted to the graded system, and better adapted than the light cruiser of Chapter 4 with low freeboard aft.

If, from other considerations, a very dark color were adopted for cruisers, it would not be possible to use the graded system. Thus the experiment might depend on the results of Experiment B.

45. Experiment D. Object: To change a 6-inch cruiser into an 8-inch cruiser.

If the 6-inch cruiser were painted a light color as Navy gray a simple design in ocean gray, illustrated in Plate 6, would sometimes make it appear similar to an 8-inch cruiser. If the major color were a dark color, the design should be a light color.

The desirability of such a deception was suggested informally by Commander Cruiser Division NINE.

46. Experiments A, B, C and D should yield results and crystallization of opinion sufficient to permit a decision to be reached concerning the painting of all Naval vessels. There is no inherent reason why all Naval ships, or all ships of a class, should be painted alike. If no single color were found which possessed outstanding virtues for all classes of ships, and if various colors or systems offered equal amounts of varied effectiveness, it would seem better to scatter the colors and systems of painting among the various classes and among the separate ships of a class, so that all ships were not painted alike.

47. Experiment E. Object: To gather data on the visibility of the wakes of ships.

It is important to know the visible ranges of the wakes of various types of Naval ships at various speeds in all types of weather and conditions of the sea surface, as viewed from the air and from the surface. It is recommended that such data be obtained and tabulated. Certain of these data for destroyers are in Chapter 2. The data are of fundamental importance in considerations of low visibility. From the table each ship can determine its circle of wake visibility for any specified condition and know whether the circle is greater or less than its circle of self visibility.

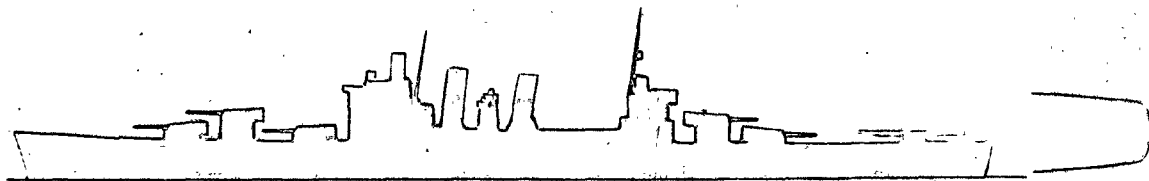
48. Experiment F. Object: To test unobtrusive dazzle camouflage on a cargo ship with raised forecastle, bridge and poop.

The unobtrusive dazzle camouflage design was fairly successful on the MELVILLE, a type of hull to which the design was not best suited (Chapter 5). It would be of interest to test the design on a type of ship for which the deception would be most pronounced, as a cargo ship with raised bridge, forecastle, and poop. Plate 14a, reference (a), gives a picture of such a ship and the details of the design.

Supplement to, or revision of, "Handbook on Ship Camouflage."

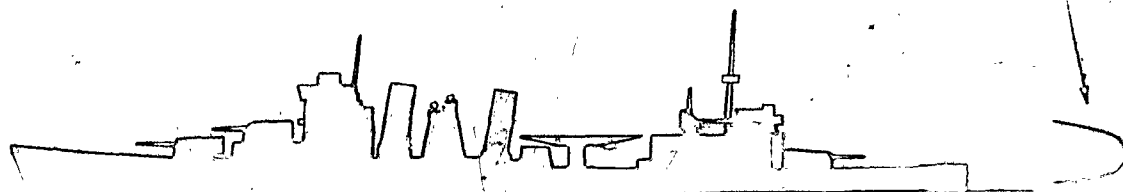
49. The knowledge and practice of ship camouflage as known in 1937 were summarized in a "Handbook on Ship Camouflage," reference (a). The results presented in the present report, which are based entirely on reference (c), agree in all respects with those of the Handbook, but add several new facts and new points of view. Eventually the

Handbook should be revised in the light of the present additional information. This could be done by the preparation of a "Supplement of 1940" to the Handbook. If no further experiments on camouflage were contemplated in the immediate future it is suggested that the supplement be prepared. If, however, further experiments were envisaged in the near future it would seem better to delay the supplement, or an entire revision of the Handbook, until the outcome of the experiments.

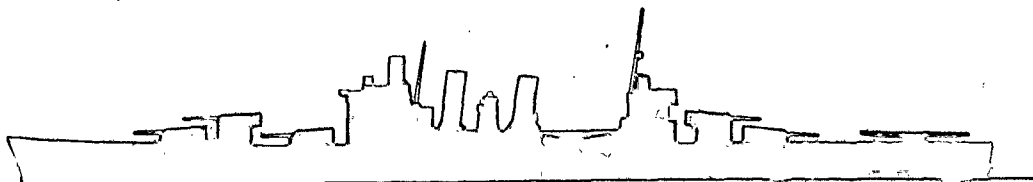


SIX INCH CRUISER

PLAN
OF
STERN



EIGHT INCH CRUISER



SIX INCH CRUISER
PAINTED TO SIMULATE
EIGHT INCH CRUISER

APPENDIX

REPORT OF COMMANDER DESTROYER DIVISION FIVE

Enclosures G, H, I, J are omitted,

and some of the photographs of

Enclosure (G) are in Plates 2,

3 and 4.

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NAVY
Bureau of Naval Ordnance

NAVY BUREAU OF NAVAL ORDNANCE
U.S. Naval, (Washington)

DEC -1 1959

SECRET

San Diego, California.

From: Commander Destroyer Division 121.
To: Commander Destroyers, Battle Force.

Subject: Camouflage Painting of Surface Vessels.

Enclosures (A) Report of Experiment 1st (Destroyers)
(B) Report of Experiment 2nd (Destroyers)
(C) Report of Experiment 3rd (Destroyers)
(D) Report of Experiment 4th (Destroyers)
(E) Report of Experiment 5th (Auxiliaries and
Merchantmen)
(F) Report of Experiment 6th (Cruisers and
Larger Vessels)
(G) Photographs
(H) Authority - Directives and History.
(I) Miscellaneous papers - Experiments etc.
(J) Report of Naval Research Laboratory No.
N-1451.

1. Commander Destroyer Division 121 was designated by Commander Destroyers, Battle Force as the representative for liaison duty with the representatives of the Bureau of Naval Ordnance and Reports; to provide for adequate and appropriate testing to direct the conduct of the experiments and to compile the reports; draw conclusions and make recommendations.

2. All experiments have been finished. A few reports have been received in the past week but it is believed they are all in.

3. a. The material is compiled in the order shown by the Enclosures to facilitate reading.

b. Experiments A, B, C, and D pertain to Destroyers. Experiment E is the final one of this group and is based on the results from the others. The report of Experiment E contains the contents of all the experiments which pertain to Destroyers.

c. Experiment D pertains to a double camouflage designed for auxiliaries.

d. Experiment E pertains to a graded system of horizontal shades designed for cruisers and larger vessels.

Enclosure 3 is a copy of the report of the committee on the subject of the color of the hull of the destroyer, Battle Force, and is attached to the report of the committee on the subject of the color of the hull of the destroyer, Battle Force.

Enclosure 4 is a copy of the report of the committee on the subject of the color of the hull of the destroyer, Battle Force, and is attached to the report of the committee on the subject of the color of the hull of the destroyer, Battle Force.

Enclosure 5 is a copy of the report of the committee on the subject of the color of the hull of the destroyer, Battle Force, and is attached to the report of the committee on the subject of the color of the hull of the destroyer, Battle Force.

4. Brief of conclusions and recommendations

Experiments A, B, C and D.

Discussion, Conclusions and recommendations are given in more detail in the report of Experiment C.

A. Conclusions:

- (1) Diesel design for destroyers is not worthy of further consideration.
- (2) Navy standard gray is not satisfactory. It is too light and has too high gloss. A dark color and a flat or matte surface is required.
- (3) Ocean gray is an improvement but it is too light in color.
- (4) Black possesses the greatest number of advantages. It is the best compromise of the three paints tested. But black is not the unanimous choice. It is best for concealment at night and from enemy aircraft under any conditions.
- (5) A dark gray between ocean gray and black is considered worth testing in comparison with black.
- (6) Gloss is objectionable in any color. A matte paint should be developed.

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Serial: C-91

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Subject: Camouflage Painting of Surface Vessels.

- (7) Dark color masts above the horizon reveal a ship at long ranges. It is believed they can be made lighter in color without serious disadvantage.
- (8) Exterior bright work and light colored surfaces are very revealing. They should be eliminated as far as possible.
- (9) Estimates of target angle and ranges are more difficult with darker colors. Stereo ranging is not affected by camouflage.
- (10) The white wakes of destroyers running at high speeds are very revealing especially at night and from aircraft under any conditions. The effect tends to offset any advantages to be had from camouflage.

B. Recommendations:

1. a. PAINT DESTROYERS BLACK MATTE ON ALL EXTERIOR SURFACES:

or, as an alternative, in order to give further consideration to a dark gray,

- b. Paint one half the number of destroyers dark gray (about the color of present deck paint) and the others black.
 - c. In order to determine the value of lighter colored masts, paint the masts of about one fourth of the destroyers Standard Navy Gray.
5. Experiment D.
- a. Conclusions -
- (1) Dangle design tends to confuse determination of target angles and coincidence ranging but this is achieved at expense of making the vessel more visible as an object.

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D. Have the 10 Control or Control center 10
and the system to develop in some way
the 10.

G. Requirements -

a. Considerations -

- (1) The guided system tends to detect the structural features of a vessel and confirm range and spotting estimates.
- (2) Unless the position of the clouded bank are related to the position of the observer the guided system is more visible than a solid color.
- (3) If standard Navy gray is to be retained for large vessels it is believed that the guided system is worthy of further tests for large vessels.

b. Recommendations -

None.

G. W. DUESEN.

ENCLOSURE (A)

of

REPORT OF COMMANDER DESTROYER DIVISION FIVE.

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VI. Experiment "C"

A. Purpose

To determine, under the conditions of the tactical exercises, the best all-around paint for destroyers, from the standpoint of reduced visibility.

B. Vessels and test materials assigned:

Destroyer Division FOUR - CUSHING - Black Matte
PERKINS - Green Matte
PRESTON - Black Gloss
SMITH - Black Matte

Destroyer Division FIVE - CASSIN - Ocean Gray Matte
DOWNES - Ocean Gray Gloss
REID - Ocean Gray Matte
CONYNGHAM - Ocean Gray Gloss

C. Determination to be made:

1. The relative efficacy of the various systems of painting under all possible conditions (day and night) encountered during the exercise and conclusion as to the best compromise for all purposes.

D. Conduct of Test:

1. As a result of previous investigation the colors chosen for this experiment were ocean gray and black. They were to be compared with standard Navy gray. The ocean gray is darker than the standard gray.

a. The four ships of Division FIVE were painted ocean gray on all surfaces visible from without except the horizontal decks. Large objects such as instruments were covered with painted cloth. The decks were painted with standard blue gray deck paint. Similarly Division FOUR was painted black, except that one ship was painted a very dark green because it had been concluded from previous experiments that, insofar as visibility is concerned, there is no appreciable difference between this dark green and black; and should the dark color be chosen there would be a choice between green and black.

b. One or more ships of each division was painted with

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VI. Experiment "C" (Continued)

D. (Continued)

a paint designated as a HIGH GLOSS. The paint furnished by Mare Island, which was designated as MATTE, proved to be glossy to almost the same extent as those designated HIGH GLOSS. In the cases of gray paints little difference in sheen was apparent. In the case of the black paint the difference was more marked but neither the high gloss nor the matte surfaces were what was expected.

2. a. The two divisions operated with the Fleet during the September Tactical Exercises which covered the period 23 - 29 September. This period afforded a variety of weather and light conditions. There were two days and one night of heavy storm during which time both divisions operated during daylight and at night. There was calm sunny weather. There was exceptionally bright moonlight from a full moon and there was morning haze. There were no dark or overcast nights. The employment of the two divisions in the Tactical Exercises afforded good opportunity for observations. One division made a night attack in the path of the moon but with the moon behind the target which resulted in silhouette most of the time but during the attack there were opportunities for observations from heavy ships from all angles relative to the bearing of the moon.
- b. During Fleet Tactical periods personnel are so completely engaged with the immediate and primary tasks of accomplishing the scheduled exercises that there were many observations made which could not be properly recorded. However, much useful information has been elicited from those who made observations through informal conversation. It should be noted too, that the colors with which the two divisions were painted had been under observation on from one to three ships for almost two months, during which time there were many opportunities for observations.

E. Discussion:

1. a. Under clear daylight a vessel is visible at long ranges regardless of color or design, and therefore

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VI. Experiment "C" (Continued)

E. Discussion: (Continued)

little success can be had from efforts to make a vessel invisible, except in the case of masts and other small and high objects which, if dark in color, are easily seen against the light background of the sky and reveal the presence of the vessel. This emphasizes the directive given by Commander Battle Force in his Serial 01163 of 20 October 1938, addressed to Bureau of Construction and Repair - COMMANDER BATTLE FORCE IS PARTICULARLY CONCERNED OVER THE QUESTION OF VISIBILITY OF DESTROYERS AT NIGHT. HE CONSIDERS THAT REDUCED VISIBILITY OF THIS TYPE IN DAYTIME MAY WELL BE SACRIFICED IF VISIBILITY AT NIGHT IS THEREBY MATERIALLY DECREASED.

- b. The nearest approach to invisibility is realized when the color of the vessel is the same as the background therefore on a gray day, in diffused moonlight or in a fog the light Navy gray is least revealing when observed from other surface vessels but when observed from the air against the dark background of the water the darker colors are less revealing. At night when there is no light sky background the darker colors are less revealing.
- c. As the source of light approaches the zenith of the target vessel, vertical surfaces come in shadow and when the source of light is in the zenith all vertical surfaces appear black and camouflage has little effect on observations from other surface vessels. Under these conditions however horizontal surfaces are affected in a contrary way and are highly visible to an aircraft observer.
- d. When the target is between the observer and the source of light it is seen in silhouette and camouflage has little effect.

2. a.

- (1) The Standard Navy gray paint is highly reflective which renders it visible at great distances under any form of concentrated light. The light color lends itself well to the formation of shadows which facilitates the determination of target

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VI. Experiment "C" (Continued)

E. Discussion: (Continued)

angles. Thus, under sunlight, moonlight or searchlight the standard gray ship is seen at long ranges and in considerable detail. At times the ship appears almost white. On the other hand, on a gray day, in fog or under moonlight diffused by clouds the light gray ship is least visible.

(2) The high visibility of the standard Navy gray paint has been the subject of adverse criticism for many years. The reports of observers throughout these experiments indicate that it is not acceptable as a compromise. The few times that it appears to advantage are far outweighed by the advantages obtained from a darker color. This conclusion comes from consideration of visibility alone. From the standpoints of smartness, ease to keep clean and effect on morale it is preferred to all other colors tested.

(3) High gloss on standard Navy gray is less apparent than high gloss on darker paints, yet it is objectionable. Reflection from the stacks and the gun mounts under concentrated light reveal the ships at long ranges.

(4) The reports of observations made from aircraft of standard Navy gray vessels are decidedly unfavorable. The light color against the dark sea background reveals the target at surprisingly long ranges while vessels painted with dark colors are invisible at relatively short ranges. The small band of standard gray along the outboard edge of the weather decks, used by some of the destroyers, brought forth the comment from aircraft observers that this light band delineated the ship clearly for a bombing target.

3. a. At the other extreme of the paints tested is black. On a gray day, in a fog the black ship is strikingly visible as an object and would attract attention of a casual observer more readily than either of the other colors tested. In a number of cases observers have reported the black ships more visible than either of the other colors. But proceeding on the hypothesis that under normal light conditions and with alert

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VI. Experiment "C" (Continued)

E. Discussion: (Continued)

lookouts there is little hope of avoiding detection, at ranges at which destroyers must operate, the black ship compares favorably with either of the other colors. Once the target is disclosed the degree of visibility becomes an academic consideration, and the advantage goes to the black ship because of the difficulty of estimating ranges and target angles by reason of the absence of contrasting shadows. Observers report however that no color affects appreciably the accuracy of stereo ranges.

b. At night black is least visible except in diffused moonlight when the black ship is visible as a black spot against the white background of the sky. Under searchlight or moonlight emanating from behind the observer black is decidedly preferable.

c. (1) Observations made from aircraft are of particular interest. They emphasize the necessity for reducing to a minimum the visibility of our destroyers from enemy aircraft. From the records available this subject has not been given due consideration in the experiments made heretofore. The observations made by aviators do not all give first place to black paint, but by far the greater majority do and a number of reports which will be referred to below are very outstanding and very favorable to black or a color approaching black. Briefs of a few of the most striking reports are given below.

(2) One senior aviator reports that on a clear day at 5000 feet black destroyers are difficult to see where as the standard gray are easily seen. (Observers Report No. 32-C)

(3) Other aviators report that darker ships are much harder to pick up under all conditions, except when in silhouette. Dark colors make estimates of target angles and course difficult. (84-C)

(4) Observations made at distances 1 to 8 miles.

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VI. Experiment "C" (Continued)

E. Discussion: (Continued)

Altitude 1000 to 2000 feet. The black ships of Division FOUR were not visible over two or three miles, while the standard gray ships were visible at all distances. The black ships were less visible than the green. Sun glints and light spots aided in locating the destroyers. Relative visibility of the camouflage ship 1/3 to 1/4 of visibility of a standard gray ship. (85-C)

- (5) Division FOUR observed - The wake of the black ships were visible at a distance of about 8 miles but the ships themselves were not seen. (87-C)

- (6) Observations made of Division FOUR, (black) together with RALEIGH and three gray destroyers. Distance of planes 15 - 20 miles and position between sun and formation. Weather slightly hazy but unlimited ceiling. The observer reports the difference in visibility striking. RALEIGH and the three standard gray destroyers were seen plainly with the naked eye, while black ships could not be seen even with binoculars although known to be present. Even with range reduced to 5 - 10 miles black ships still very difficult to make out with glasses. Speed of ships was 12 knots; therefore no wake and as pointed out before the wake is the most visible feature in picking up dark colored destroyers from the air. The opinions of the pilots of Patrol Squadron TWELVE are that the black vessels are at least equal to the standard gray under any conditions and definitely superior under most conditions observed. No observations made in fog or low visibility. On several occasions in Fleet Tactical Exercise 207 patrol planes trailing major units with distant destroyer screens - while patrolling at a distance assumed to be beyond visibility of all ships, had the disconcerting experience of picking up black destroyers so close as to be well within effective gun range. And in every case ships were sighted first by the white wake alone. (88-C)

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VI. Experiment "C" (Continued)

E. Discussion: (Continued)

- (7) Observation of Destroyer Division FOUR. Ships very hard to see against hazy background but wake was clearly visible. When joined by standard gray ship it was noted that the reflection of the sunlight from the standard gray made them plainly visible, while the black and dark green ships were nearly invisible. No difference noted between the black and dark green. (89-C)
- (8) Observation of Division FOUR. Altitude 5000 feet. Sun behind the observer. Clear weather. Standard gray destroyers appeared white and were visible up to 15 miles while Destroyer Division FOUR could only be seen with great difficulty at slant ranges under two miles and then with no definite assurance as to the dimensions or silhouette. (90-C)

4. a. Ocean gray is in the color scale between black and the standard gray. On a bright sunny day it is reported by observers from surface vessels as the least visible of the three colors and compares favorably with either of the other two colors under any chosen conditions. It does not appear white under concentrated illuminations as does the standard gray and is less striking than black on a clear bright day. If the aerial observations were excluded it is believed that ocean gray, or a somewhat darker gray, would be chosen by the majority as the best compromise color. It is believed however that preference for the ocean gray over the black is influenced by the following factors:

Natural aversion to solid black ships, especially flat black, from standpoint of smartness and difficulty of upkeep.

In daylight the black ship presents a silhouette which is more clearly delineated than the ocean gray and therefore is said to be more visible.

- b. The first of these factors, smartness and cleanliness, although not a part of this investigation,

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VI. Experiment "C" (Continued)

E. Discussion: (Continued)

will inevitably influence the opinions of officers who go to sea on surface vessels. The second factor is in part an optical illusion. A black ship is more striking than a gray ship even at close range. It is therefore said to be more visible, despite the fact that definition of detail is better in the case of the gray ship and therefore the target angle is easier to estimate.

It is believed that the ocean gray tested is too light a gray and that if gray be chosen it should be considerably darker. A dark gray would have most of the advantages of black and would probably meet most of the objections advanced to black. The results of the tests seem to point to a very dark color - darker than ocean gray. A conclusion as to how far short of black the color could be, cannot be drawn from these Experiments.

F. Conclusions:

1. Standard Navy gray is not satisfactory either for daytime or night.
2. A color much darker than Navy gray and darker than ocean gray is indicated.
3. Preference for the three colors tested is, in order, Black, Ocean Gray, Standard Gray. Black meets the requirements for improved visibility at night, in accordance with Commander Battle Force's directive, that daytime visibility may well be sacrificed for decreased visibility at night.
4. Ocean gray is second in choice to black but aviation observations are definitely in favor of black and many surface observers prefer black.
5. A gray, much darker than ocean gray, would be preferred to black by destroyer personnel and would possess most of the advantages of black.
6. The dark green tested is almost the same as black but not quite as satisfactory.

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VI. Experiment "C" (Continued)

F. Conclusions: (Continued)

7. Gloss is objectionable in any color. It is most apparent on stacks and guncholds and is most noticeable with black. A matte paint is required and should be developed.
8. The best Navy paints are glossy. A small sample of Sherwin - Williams matte black was tested and gave promising results.
9. A related subject is the elimination of exterior reflecting surfaces - These include bridge windows, ports, port rims, turnbuckles, whistles, gun parts, binnacles, bright woodwork, such as varnished benches and boat decks.
10. All surfaces visible from the air should be black or a color approaching black. These include canvas of all kinds.
11. Exposed ring life buoys should be the same color as the surrounding surfaces.
12. Black masts and similar high structures are very revealing when they alone protrude above the horizon. Standard Navy gray color is believed to be best for them. It is believed masts can be painted standard gray without materially increasing visibility.
13. At speeds above 12 knots the white wake of a destroyer becomes an important consideration in efforts to avoid detection. At night and from aircraft at any time, when destroyers are making speeds of 20 knots and above, the wakes are so apparent that little advantage can be had from camouflage.

G. Recommendations:

1. a. Paint destroyers black matte on all exterior surfaces; or as an alternative, in order to give further consideration to dark gray,
- b. Paint one half the number of destroyers dark gray (about the color of present deck paint) and the others black.

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VI. Experiment "C" (Continued)

G. Recommendations: (Continued)

- c. In order to determine the value of lighter colored masts, paint the masts of about one fourth of the destroyers standard Navy gray.
2. Paint, dye or cover all surfaces visible from without so that the exterior will present a uniform color at all times when operating at sea.
3. Eliminate exterior brightwork and, as far as possible, all high reflecting surfaces including varnished woodwork.
4. Paint bow numbers with a color lighter in shade than the hull but such that there will be small contrast between the two colors.
5. Operate with these systems for one year. Request comments from the Fleet once each quarter.

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II. Experiment "B"

A. Purpose.

To evaluate the relative advantages of dark green, black, and ocean gray paint, matte and glossy with special reference to night attacks but with some indication of relative visibility during the day-time.

B. Vessels and Materials assigned:

Destroyer Division FOUR - CUSHING	- Green Glossy.
PERKINS	- Green Matte.
PRESTON	- Ocean Gray.
SMITH	- Black.

C. Determinations to be made:

1. The relative visibility at night of the various systems of painting under both natural and searchlight illumination.
2. If the glossy paint is any more revealing than the matte paint.
3. The relative visibility of these paints during the daytime with special reference to the thought that if the darker colors are best for night, are they too dark for day work, in view of the desirability of obtaining a color representing the best compromise for all conditions.

D. Conduct of Test:

- (a) The vessels of Destroyer Division FOUR were painted as noted in B above. During their normal operations they were observed by units as encountered and reports submitted as required.

See Observers Sheets Number 1-B to 13-B inclusive, 16-B and 17-B.

E. Conclusions:

1. From a low visibility point of view there is no distinction between black and green, both being equally visible in clear or overcast daytime weather.

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II. Experiment "B"

E. Conclusions (Continued).

2. Ocean gray highly visible in overcast weather but least visible with reference to black and green on sunny clear days.
3. All paint furnished was of a relatively high gloss.
4. Gloss paints materially aid in disclosing the ship under any form of concentrated light day or night. It is most noticeable with the darker paints.
5. Since any color is visible in practically every condition of weather in daytime, a paint to decrease their visibility at night under searchlight is most desirable.
6. A true black matte paint is the best color for concealment at night under all conditions except in diffused moonlight as obtained with an overcast moon.

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NOTES BY MR. BITTINGER ON EXPERIMENT "B"

Visibility of ships painted dark green, black and ocean gray:

From a low visibility camouflage point of view there is no difference between the black and green ships. They were always clearly visible in daytime when the weather was clear or overcast. Any choice between these two colors would be a matter of a pleasant living environment, ease of keeping clean, absence of eye strain to the personnel and stability of the paint.

Ocean Gray

The ship painted ocean gray (PRESTON) was always visible in overcast weather. On sunny clear days it was the least visible ship of the Division, and with the sun behind the observer and on the ocean gray ship it was least visible of all the paints.

Gloss

With one exception all the observers' records indicate that there was no difference between the gloss and matte colors in daytime; however, the paint furnished for these tests was all of a relatively high gloss.

NIGHT ATTACKS

Although there are no records of night attacks requested in Experiment "B" the tests made at night under Experiment "A" indicate clearly that the gloss on the dark ships does make them visible under searchlight at night, and that only matte paint should be used on the dark ships. In view of the fact that the Destroyers are going to be seen anyhow in practically every weather condition in daytime - would it be desirable to paint them so that they would be invisible at night under searchlight.

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Enclosure (B)

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ENCLOSURE (C)

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U.S.S. CASSIN (Flagship)

Experiment "A"

A. Purpose.

To determine the best compromise color for low visibility in all circumstances of weather, illumination, sea areas and employment.

B. Vessels and test material assigned:

Destroyer Division FIVE - CASSIN	- Ocean-Gray.
DOWNES	- Black.
REID	- Standard Navy Gray.
CONYNGHAM	- Dazzle of Black and Ocean Gray.

C. Observations to be made by:

- (1) Other surface vessels.
- (2) Submarines.
- (3) Aircraft.

D. Determinations to be made:

(a) Relative visibility of vessels:

- (1) In various types of smoke screens.
- (2) Under various weather conditions during the day.
- (3) At night under both natural and searchlight illumination.
- (4) Operating in various areas.

(b) Relative ease of:

- (1) Course estimation.
- (2) Range finding.

E. Conduct of Test.

1. Determination of relative visibility in various types of smoke screens.

a. Aircraft smoke screen.

Two aircraft were employed, one to lay smoke and the other to observe. In addition, the CLARK was stationed abeam of the target division to make observations. The wind was 15 knots from astern of the destroyers in column.

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DESTROYER DIVISION FIVE
U.S.S. GARDEN (Flagship)

~~Destroyer Division~~ (Continued)

The screens were laid down wind and near the target division which was in column. Two screens were laid. The first was light and ineffective. The second was heavier but was dispersed by the wind before the target ships could advance through it as was intended. Observations are typical of a view of vessels through a smoke screen just as it lifts; as in a light fog. See Observers Sheets Numbers 1-A and 2-A - and photographs.

b. Ship's smoke screens.

(1) Boiler Smoke.

The conditions were typical of vessels coming through a light boiler smoke screen. See Observers Sheet Number 3-A and photographs.

(2) F. S. Mixture.

The wind conditions were such as to disperse the screen rapidly and limit the value of observations. See Observers Sheet Number 4-A and photographs.

(3) Combination boiler smoke and F.S. Mixture released simultaneously.

The screen was heavy and appeared successful but began to dissipate before ships emerged. See Observers Sheets Number 5, 6, 7-A and photographs.

2. Determination of relative visibility under various weather conditions during the day.

- a. Division FIVE was maneuvered during operating periods from 31 July to 1 September in various daylight atmospheric conditions and at various distances, in company with the CLARK. Observations were made and reported by CLARK and other vessels encountered. Special runs were observed from the submarine S-28 by the Commanding Officer and Mr. Bittinger. See Observers Sheets Number

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U.S.S. CASSIN (Flagship)

Experiment "A" (Continued)

8-A to 27-A inclusive and 33-A to 38-A inclusive.

3. Determination of relative visibility at night under both natural and searchlight illumination.

The division was maneuvered under both conditions as in night attacks on the CLARK which ship provided the searchlight illumination. See Observers Sheets Number 28 - 31-A inclusive.

4. Determination of relative visibility of vessels operating in various sea areas.

SOMERS, WARRINGTON, and GRIDLEY while enroute East to West Coast made observations in various latitudes under various atmospheric conditions. SOMERS - Ocean Gray; GRIDLEY - Warrington, Standard Navy Gray. See Experiment "F".

5. Relative ease of course or target angle estimation and range finding.

All reports of observations include comments in regard to these features.
See Observers Sheets Number 8-A to 27-A inclusive and Number 32-A to 38-A inclusive.

F. Conclusions:

In all sunlight and moonlight data with source of light behind the observer:

1. Navy standard gray is least visible on a gray day, overcast or hazy day.
2. Ocean gray is least visible on a bright sunny day.
3. Black is least visible at night except under moonlight diffused through clouds. In the daytime black ships are visible at long ranges as objects but target angles are much more difficult to determine than with lighter paints.
4. The dazzle design is confusing under certain conditions but not sufficiently so to warrant further

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Experiment "A" (Continued)

consideration for destroyer painting.

5. In silhouette camouflage effect is negligible.
6. In black darkness camouflage effect is negligible.
7. Glossy paint possesses high degree of reflectivity when viewed under any strong light, natural or artificial.
8. Stacks were most marked reflecting surfaces.
9. In overcast diffused moonlight without searchlight ships painted black were more visible between ranges of 7000 to 4000 yards than were gray ones.
10. At 2000 yards range, in moonlight without searchlight standard navy gray ship was lighter than the background.
11. In boiler smoke, black and ocean gray are least visible.
12. In F.S. smoke standard navy gray is least visible.
13. In F.S. and boiler smoke mixture, the black and ocean gray are least visible.
14. The darker the paint the more difficult the determination of target angles.
15. Black confuses estimate of target angle in any light.
16. Details on standard navy gray and ocean gray ships are easily discernible and assist in target angle estimates.
17. At night under searchlight a high speed wake is clearly visible and readily discloses presence of a destroyer regardless of painting.

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NOTES MADE BY MR. BITTINGER ON EXPERIMENT "A"

In all sunlight and moonlight data it is understood the light is behind the observer and incident on the target ship.

Low Visibility - Daytime

- (a) Navy Gray is best for overcast hazy weather.
- (b) Ocean Gray is best for clear sunny weather.

Low Visibility - Moonless night

- (a) There seems to be little difference what color the Destroyer is painted when observed under the light from the stars; however, in every case under search-light the dark ships were the least visible (Reference is repeatedly made to the gloss highly reflecting surface of the black paint - the reflection of the light from the stacks was especially marked in each observers record.

Low Visibility in Moonlight.

In the one observation made with the ships in moonlight the black ships appeared more visible than the gray ships at 7000 yards. This was also true at 4000 yards. At 2000 yards the Navy Gray (REID) appeared lighter than the sky background and the Ocean Gray (CASSIN) was practically invisible.

Low Visibility - Black Smoke Screen

The atmosphere or wind on the days the smoke screen was used prevented the smoke, especially the black smoke from remaining on the water. In view of this fact the data obtained at these tests is of little value. However, in the black smoke the dark ships were the least visible.

Low Visibility F.S. Smoke

The observer of the first test stated that the black (DOWNES) and the dark dazzle (CONYNCHAM) "merged into a solid mass", whereas the (REID) navy gray, was plainly delineated." This anomaly can only be accounted for by the uneven density and general ineffectiveness of the screen. On the second test the darker ships were more visible than were the light ships - which was to be expected.

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NOTES MADE BY MR. BITTINGER ON EXPERIMENT "A" (Continued)

Low Visibility - F.S. and Black Smoke Combination

In this screen the darker ships were a little more visible, but there was not a great deal to choose between them. The screen was not opaque.

Dazzle - Course Distortion

The dazzle ship (CONYNGHAM) was painted with a modified dazzle design. To make the ship low visibility for a night torpedo attack under searchlight, the ship forward of the bridge structure was practically all black. Course distortion was only possible when the target angle was more than 45° and less than 315°. With this limitation the course distortion was fairly effective. In the black smoke screen the dazzle ship (CONYNGHAM) "was very difficult to see, its target angle was very difficult to distinguish." In overcast hazy weather "the (CONYNGHAM) target angles were the most difficult to determine." This is also true for clear sunny days.

Although the DOWNES was painted black for low visibility under searchlight - (numerous references are made in the reports about the difficulty in daytime of obtaining target angles on the black ship). This is due to the fact that most of the shadows from the detail of the superstructure cannot be seen owing to lack of contrast. While the details on the CASSIN (Ocean Gray) and especially the REID (Navy Gray) are "easy to pick out".

Numerous references are made to the black ships appearing at a shorter range than the gray ships, in overcast weather.

It is suggested: that a black wartime paint be developed, the first requirement of which would be that when this paint was applied to a metallic structure - the surface of this paint, when dry, would be completely diffusing and perfectly matte.

It has been stated that paint containing varnish has more lasting qualities. There is no question about the truth of this statement. However it does not follow that a paint cannot be developed which would have equivalent lasting qualities without this gloss-producing varnish.

To prove that a black matte paint can be made which will

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U.S.S. CASSIN (Flagship)

NOTES MADE BY MR. BITTINGER ON EXPERIMENT "A" (Continued)

possess lasting qualities - some Sherwin-Williams black matte paint was bought in San Diego a sample of which was applied to the bow of the U.S.S. REID at the waterline where the greatest erosive effect on the paint might be expected.

The enclosed photographs show the REID with the sample of black S. & W. matte black sample on the bow of the REID is practically in perfect condition, while the gloss Navy black on the bow of the DOWNES has lost about 20% of its surface.

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Enclosure (C)

ENCLOSURE (D)

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DESTROYER DIVISION FIVE
U.S.S. CASSIN (Flagship)

V. Experiment "F"

A. Purpose.

To determine the relative value of Ocean Gray Paint as compared to the present Navy Standard Gray Paint in other areas than the San Diego area.

B. Vessels assigned and test material.

SOMERS - Ocean Gray.

WARRINGTON - Navy Standard Gray.

GRIDLEY - Navy Standard Gray.

C. Time of Test.

Test was conducted while vessels concerned were enroute to the West Coast during June and July 1939.

D. Conduct of Test.

The Bureau's representative Mr. Charles Bittinger was embarked in the GRIDLEY at Panama, C.Z. Numerous observations were made both at day and night, with and without searchlight illumination.

See Observers Sheets Number 1-F to 25-F inclusive.

E. Conclusions.

1. The relative visibility of the ocean gray and standard gray is the same in any area under similar weather and light conditions.

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RELATIVE VISIBILITY OF NAVY GRAY AND OCEAN GRAY IN THE
Atlantic and Pacific Oceans.

With the sun behind the target no painting has any important effect on visibility.

With the sun behind the observer and shining on the target the ocean gray ship was much lower visibility.

In overcast weather the Navy gray ship was lower visibility.

This test is of interest as it is the first made of Ocean Gray in the Atlantic Ocean. It seems from these reports - that with given conditions of atmosphere and Sun - there is no great difference between the visual effects in the Atlantic or Pacific Oceans.

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IV. Experiment "E"

A. Purpose.

To determine if the efficacy of the graded method of camouflage is changed by its application to a larger vessel.

B. Vessel assigned and test material.

The DETROIT and RALEIGH were assigned to this test, the former retaining it's normal painting and the latter painted according to the graded method.

C. Determinations to be made:

1. If the graded method of painting under various conditions of weather has any effect in so far as range estimation is concerned.
2. The relative visibility of the two methods of painting (normal and graded).

D. Conduct of Test.

The DETROIT and RALEIGH were observed during their scheduled operations by vessels encountered and observations submitted.

See Observers Sheets Number 1-E to 8-E inclusive.

E. Conclusions.

1. The graded method does materially confuse range estimation.
2. In hazy weather the graded vessel was more easily discernible than the normal vessel.
3. In clear bright weather there is little choice in relative visibility of the two methods of painting.
4. Painting smokepipe watch caps at varied heights assists confusion of range estimation.
5. Possibility of being especially advantageous submarine attacks where only quick glance thru periscope possible.

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Enclosure (E)

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U.S.S. CASSIN (Flagship)

NOTES BY MR. BITTINGER ON EXPERIMENT "E"

GRADED SYSTEM

If a ship is painted all over the same color as the sky and if the ship is "this side" of the horizon, one received the impression that a narrow strip of sky has been brought down in to the sea, and the lower edge of this strip is the water line of the ship.

The purpose of this experiment is to subjectively remove the water line, and to place it where it does not exist.

The graded system is designed to have about the water line a color of the sea and above, a color which matches the color of the sky. In other words to paint the ship the color of the sea - where the sea is the background and to paint the ship the color of the sky - where the sky is the background.

As the color of the sky is constantly changing, it is very seldom the ship actually disappears. However the color of the sea is easily matched and by removing the water line, the impression is given of the ship being at a greater distance than it really is.

The inclosed photographs give some idea of the increased range of the RALEIGH compared to the DETROIT (the ships were in column); however, the subjective impression gave a much greater difference in the range than the photographs indicate.

In a previous test of the graded system on a Destroyer the stereoscopic range finder had great trouble getting the range but after the correct range was obtained from a coincidence range finder the variations could be recorded on the stereoscopic instrument.

Like the camouflage on the port side of the MELVILLE the graded system is new, not conspicuous, and would in no way arouse the suspicions of an enemy until he made corrections for the splash of his projectiles.

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ENCLOSURE (F)

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U.S.S. CASSIN (Flagship)

III. Experiment "D"

A. Purpose.

To determine if a dazzle design is of any value when applied to tenders or to merchant vessels.

B. Vessels assigned and test material.

The U.S.S. MELVILLE was assigned to this test and painted in accordance with instructions issued by the Bureau's representative Mr. Charles Bittinger. The design applied is illustrated in the photograph marked Sheet 1-D.

C. Time of Test.

The MELVILLE was painted and observed at sea on 5, 6, 7 and 8 September by various units encountered.

D. Determinations to be made.

The efficacy of the design in confusing course and range estimations.

E. Conduct of Test.

1. The MELVILLE was observed by various units encountered in the operating areas.

See Observer's Sheets Numbers 2-D to 6-D inclusive, 8-D to 16-D inclusive.

2. The U.S.S. ZANE with Mr. Bittinger aboard was used to make prescribed observations.

See Observer's Sheet Number 7-D and inclosures thereto, and 8-D.

F. Conclusions.

1. The target angle was appreciably distorted by camouflage on both sides especially from approximately 30° to 160° and 210° to 330°.
2. The presence of camouflaging is less evident by method applied to port side than by that applied to starboard side.

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U.S.S. CASSIN (Flagship)

III. Experiment "D".

F. Conclusions (Continued)

3. Camouflage is ineffective at night without artificial illumination.
4. Under searchlight illumination camouflage has the same effect as in daylight.
5. The application of camouflage to the masts and tops would materially assist in its effectiveness.

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U.S.S. CASSIN (Flagship)

NOTES BY MR. BITTINGER ON EXPERIMENT "D"

The general principles of disguising the course of a ship by dazzle camouflage were studied during the last two years of the Great War I.

The designs used were bold contrasting forms which while subjectively changing the course of the ship - greatly increased the ships visibility.

The Bureau of Construction and Repair at the Naval Research Laboratory some experiments which had to the development of a new form of dazzle - which would not increase the visibility.

To make a practical test of this new development it was decided to paint a merchant ship, as the merchant ship has the cargo wells, forward and aft, and the sides of the ship are carried up on the superstructure amidships. These details were considered essential to the success of the design.

Unfortunately no ship of the merchant design type could be found, which was under the jurisdiction of Commander Destroyers, Battle Force, so it was decided to see what could be done with the MELVILLE and her port side was painted with the new design. To compare the new ideas with the old camouflage - the starboard side of the MELVILLE was painted with a bold contrasting design.

Unless an observer had been told the port side of the MELVILLE was camouflaged he would never know it from looking at it. Because of this fact, an enemy would not be as suspicious as he would be at the sight of the conventional dazzle.

In making test observations of the course of a dazzle ship - it is essential that a record be made of the true course of the ship at the time the observations were made - because one can easily be deceived.

The observations of the ZANE are a model as they combine conciseness and accuracy.

Being self-explanatory the report from the ZANE is submitted for consideration.

The only recommendation is that this new idea be tried out on a merchant ship - when one is found available. As the subtle visual effects, produced by the camouflage on the port side of the MELVILLE are new and have decided possibilities.

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U.S.S. CASSIN (Flagship)

NOTES BY MR. BITTINGER ON EXPERIMENT "D" (Continued)

NOTE:

Certain parts of the MELVILLE were not painted (such as the Bridge) and certain structural changes were not made (such as twisting the yard tipping the motor launches, etc.). These details would amplify the course distortion, and would be done when camouflaging a ship for the war zone.

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